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Intelligence 33 (2005) 39–65

INTELLIGENCE

Ability-based pairing strategies in the team-based training of a complex skill: Does the intelligence of your training partner matter?

Eric Anthony Day[a,*], Winfred Arthur Jr.[b,*], Suzanne T. Bell[b], Bryan D. Edwards[b], Winston Bennett Jr.[c], Jorge L. Mendoza[a], Travis C. Tubré[b]

[a]Department of Psychology, The University of Oklahoma, 455 W. Lindsey, Room 705, Norman, OK, 73019-2007, United States
[b]Department of Psychology, Texas A&M University, 4235 TAMU, College Station, TX 77843-4235, United States
[c]U.S. Air Force Research Laboratory, United States

Available online 5 November 2004

Abstract

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Keywords: Interindividual; Intelligence; Dyadic training teams

* Corresponding authors. Eric Day is to be contacted at, Tel.: +1 405 325 3237; fax: +1 405 325 4737. Winfred Arthur, Jr., Tel.: +1 979 845 2502; fax: +1 979 845 4727.

E-mail addresses: eday@ou.edu (E.A. Day); wea@psyc.tamu.edu (W. Arthur).

0160-2896/$ - see front matter
doi:10.1016/j.intell.2004.09.002

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
JAN 2005	**Journal Article**	**00-01-2003 to 00-12-2004**

4. TITLE AND SUBTITLE
Ability-based pairing strategies in the team-based training of a complex skill: Does the intelligence of your training partner matter?

5a. CONTRACT NUMBER
F41624-95-C-5007

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
62202F

6. AUTHOR(S)
Eric Day; Winfred Arthur Jr; Suzanne Bell; Bryan Edwards; Winston Bennett Jr et al

5d. PROJECT NUMBER
1123

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Air Force Research Laboratory/HEA,Warfighter Training Research Division,6030 South Kent Street,Mesa,AZ,85212-6061

8. PERFORMING ORGANIZATION REPORT NUMBER
AFRL; AFRL/HEA

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Force Research Laboratory/RHA, Warfighter Readiness Research Division, 6030 South Kent Street, Mesa, AZ, 85212-6061

10. SPONSOR/MONITOR’S ACRONYM(S)
AFRL; AFRL/RHA

11. SPONSOR/MONITOR’S REPORT NUMBER(S)
AFRL-RH-AZ-JA-2005-0001

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Published in Intelligence 33(1), 2005, pp 39-65 Additional authors: Mendoza, J.L., & Tubre, T.C.

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15. SUBJECT TERMS
Ability-based pairing; Strategies; Team-based training; Team training; Complex skills; Intelligence; Training; Attention; Intelligence-based composition; Training teams; Computer-based criterion; Skill acquisition; Interindividual; Dyadic training teams

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Public Release**	**27**	

1. Introduction

It is well established that intelligence is not only a robust predictor of scholastic achievement (Jensen, 1993) and job performance (Ree & Earles, 1992; Schmidt & Hunter, 1998) but also a critical variable associated with behavior across the majority of everyday life events (Barrett & Depinet, 1991; Gordon, 1997; Gottfredson, 1997). Although the evidence regarding the ubiquity of the importance of intelligence is substantial, researchers traditionally have focused their attention on the individual level of analysis and frequently have overlooked the role of intelligence in interindividual contexts (Gordon, 1997), which involve two or more individuals interacting with each other. In particular, researchers have neglected to study the interplay of the effects of intelligence at the individual and team or group levels. Within interindividual contexts, the intelligence of individuals is associated with a confluence of group and individual effects. However, a surprisingly limited amount of research has explored this confluence of effects. This is not to say that previous researchers have ignored how team members' intelligence is related to team functioning. Indeed, enough research has been conducted to allow researchers to meta-analytically examine the relationship between member ability and team performance (e.g., Devine & Philips, 2001). However, studies investigating how intelligence as a team composition variable simultaneously affects team and individual outcomes are lacking.

Accordingly, the objective of the present study was to investigate the relationship between intelligence and the effectiveness of dyadic training teams. Specifically, we systematically created high (HH)-, low (LL)-, and mixed (HL)-ability dyadic teams on the basis of intelligence scores to examine how team composition affects the learning and performance of a complex skill at both team and individual levels. We examined the potential nonadditive effects of homogeneous high-ability teams and the extent to which individual trainees' skill acquisition was influenced by their team performance and the ability of their partners. Given that much of human learning takes place in a social context and coupled with the dearth of empirical investigations examining intelligence at the interindividual level, we believe that the present study makes an important contribution to the existing literature on intelligence. Considering the rapid pace at which technology is advancing, many work tasks now consist of physical and cognitive demands that are too diverse and complicated for most individuals to successfully accomplish single-handedly. Consequently, reliance on teams is now a pervasive reality in many military and civilian settings. Therefore, in the present study, we chose to examine the role of intelligence in the context of learning and performing a complex task comprised of multiple interdependent components. Effective performance on this task requires successfully coordinating the interchange between these task components.

2. Learning and intelligence in interindividual contexts

In addition to the important roles that family members, teachers, trainers, mentors, and coaches play in human learning, there is a strong social context to learning with children and adults frequently acquiring knowledge and skills in team and group settings. Children learn to play musical instruments by performing in bands and orchestras. Similarly, children learn to play sports by joining local area and school teams. It is common for students to be assigned partners for class projects and even for more sustained schoolwork as is the case of laboratory partners in science classes. Military recruits undergo basic training in a team context. New hires for entry-level job positions frequently train with other new hires, whether on the job or offsite in a classroom.

A common issue across many domains is that, as individuals progress in their knowledge and skills, the composition of the teams and groups in which they practice and perform changes. This is true even when the outcome of primary interest is team performance. The composition of an individual's high school orchestra will typically not closely resemble the individual's middle school orchestra. One is likely to have different laboratory partners across science classes and grade levels. The transient nature of teams is apparent even in settings where the stakes of team performance are very high (that is, there are substantial costs associated with failure). For example, it is not uncommon in the military for teams to disband after training, and, for their operational assignments, individuals are then reassigned to other teams and paired with partners with whom they had no contact during training. In general, team composition changes over time, and individuals find themselves performing alongside different teammates. Considering that a team's performance is largely determined by the competency of its individual members (Salas, Bowers, & Cannon-Bowers, 1995), and intelligence is a key determinant of individual learning and team performance, it is important to examine the individual- and team-level effects of team training and also examine the extent to which individuals' learning is influenced by the intelligence of their training partners. Furthermore, it is important to consider how this influence relates to the actual performance of the training team.

It has long been acknowledged in the psychological literature that much of learning takes place in interindividual contexts. Piaget (1977), for example, recognized that social life is a necessary component of cognitive development. Despite acknowledging the interindividual context, intelligence researchers in their empirical work are accustomed to focusing on the individual learner and ignoring the learner's social surroundings. Failing to take into account the role of intelligence at an interindividual level underestimates the impact of intelligence on human behavior (Gordon, 1997). However, when it is taken into account, the interindividual context is typically characterized in terms of social variables. Alternatively, researchers frequently treat the intelligence of persons outside their focus of analysis as a source of error rather than as a critical part of the phenomena they are investigating (Gordon, 1997).

To allow appropriate inferences regarding the interplay of the effects of intelligence in individual and interindividual contexts, three principle design factors must be present. First, the intelligence of the focal individuals must be assessed. Second, the intelligence of the persons within the individuals' given context must be assessed. Third, both individual and interindividual (i.e., team) assessments of the criterion of interest should be conducted. These kinds of data, nevertheless, are difficult to generate even in contrived settings for purposes of study (Gordon, 1997). In the rare case when researchers attempt to assess the influence of the ability of important others, such as helpers or partners, ability is often operationalized in terms of the level of competence on the criterion task prior to experimental manipulations rather than in terms of an independent test of ability (e.g., Dossett & Hulvershorn, 1983; Tudge, 1999). Misspecifying the ability construct in this manner makes it difficult to draw inferences about the influence of intelligence at an interindividual level.

Our review of the intelligence literature failed to identify any empirical studies that had these design features and examined individual and team performance where the same participants performed in teams and as individuals. Such research is needed to appropriately examine the mutual influence of intelligence at the individual and interindividual levels on learning and performance. It has been well established that the intelligence of individual team members influences their performance as a team. However, what has not been adequately addressed in the empirical literature is the extent to which individuals learn from their team's performance. It is likely that individuals acquire higher levels of knowledge and skill when their teams perform at high levels. That is, intelligence at the interindividual level affects both team performance and individual learning.

Researchers commonly examine the relationship between individual intelligence and individual performance as well the relationship between overall team member intelligence and team performance. Although less common, researchers have also examined the interaction between team members' intelligence levels with respect to team performance. Researchers have even compared how teams with members of varying levels of intelligence perform relative to individuals of varying levels of intelligence. For example, Laughlin and Johnson (1966) had college students complete Terman's (1956) Concept Mastery Test, and, later, half of the participants completed the test a second time as individuals and the other half in pairs. The pairs were formed based on high (H), middle (M), or low (L) performance on the first administration. Thus, at the dyadic level, there were six types of teams that differed in terms of their ability combinations: HH, HM, HL, MM, ML, and LL. With the exception of LL pairs, who performed no better than L individuals, the results showed that participants working with partners of higher or equal ability scored higher relative to participants working individually or with partners of lower ability. Laughlin and Johnson concluded that there may be more heterogeneity of requisite knowledge at higher ability levels relative to lower ability levels, which in turn allows higher ability individuals to make unique contributions to their teams. In contrast, they posited that a high degree of knowledge overlap at lower ability levels results in little value added at the team level, thus obviating collaboration. Such a conclusion is also consistent with their finding that HL pairs did not perform better than H individuals, and ML pairs did not perform better than M individuals. Although Laughlin and Johnson examined intelligence at an interindividual level by comparing team to individual performance, they did not address the extent to which the effects of intelligence at an interindividual level (in terms of team functioning) transfer to individual learning and subsequent individual performance.

In the next two sections, we briefly review the separate literatures on how the intelligence composition of teams relates to team and individual performance. We then advance a set of hypotheses that integrates these separate literatures and addresses the additive and potential nonadditive influences of intelligence in interindividual contexts. Accordingly, we present an experiment involving training teams of different intelligence compositions that was designed to test these hypotheses and to highlight the interdependence of team performance and individual learning as they both relate to intelligence.

3. Ability-based team composition effects

Investigating the relationship between team members' intelligence and team performance is a starting point for understanding the interindividual nature of intelligence. Most of the research relating team composition to team performance comes from the social and industrial and organizational psychology literatures. Within these literatures, substantial empirical evidence has indicated that, under a variety of conditions, team members' ability is predictive of team performance. However, the observed relationships vary according to the operationalization of team-ability and the type of task employed (Devine & Philips, 2001). Moreover, although several recent studies have examined team composition effects on performance (e.g., Barrick, Stewart, Neubert, & Mount, 1998; LePine, 2003; Neuman & Wright, 1999), the primary limitation of the existing research is that critical team composition variables, like intelligence, have rarely been manipulated. Only a handful of studies (e.g., Goldman, 1965; Graham & Dillon, 1974; Laughlin & Johnson, 1966; Tziner & Eden, 1985) have formally examined the effects of a priori determined team or group compositions on resulting performance. Of these studies, Tziner and Eden's (1985) work is often cited in the team composition literature as their findings reflected both additive as well as nonadditive (i.e., synergistic) effects for team ability.

Tziner and Eden (1985) experimentally manipulated the ability composition of three-person tank crews in a field setting. Although strong additive effects were found, a nonadditive effect was also observed such that teams uniformly high in ability performed significantly better than that predicted from team member abilities. Similarly, teams that were uniformly low in ability performed worse than expected from team member abilities. In the discussion of their findings, Tziner and Eden stated that team performance is "likely to relate positively to the summed abilities of all group members" (p. 90). Furthermore, they emphasized that positive nonadditive effects can occur when a team is composed of all highly capable individuals. As long as uniformly low-ability teams can be avoided, "talent [ability] is used more effectively when concentrated than spread around" (p. 91). These inferences are consistent with the aforementioned conclusions of Laughlin and Johnson (1966).

Although researchers have discussed the importance of studying nonadditive composition effects in teams (e.g., Moreland, Levine, & Wingert, 1996), nonadditive effects, like those obtained by Tziner and Eden (1985), are rare in the literature. Indeed, the importance of Tziner and Eden's study is evident as researchers (e.g., LePine, 2003) almost exclusively point to Tziner and Eden's results when making statements about the potential nonadditive effects of ability in teams. Thus, it is worthwhile to replicate and extend Tziner and Eden's findings. A key purpose of the present investigation was to examine the effects associated with a manipulation of the ability composition of training teams. Not only were we interested in replicating the nonadditive effects demonstrated by Tziner and Eden, we also sought to extend their study in several ways. First, we used a laboratory task that yielded objective performance scores, whereas Tziner and Eden used subjective rankings of performance made by supervisors. Second, in contrast to Tziner and Eden's single assessment of performance, we assessed performance repeatedly during training. Lastly, we demonstrate the interplay between the interindividual and individual levels by examining the effects of ability composition on individual performance.

4. Ability-based pairing strategies and individual learning

Although the performance of teams and groups may be an important criterion of interest to researchers, limiting the study of the ability composition of teams to team-based criteria provides an incomplete view of the dynamic nature of intelligence and the interplay between interindividual and individual phenomena. A more comprehensive approach to studying the dynamic nature of intelligence is to also examine the consequences of intelligence-based composition strategies on individual learning. This provides a direct connection between the interindividual and individual levels and their relationships to intelligence.

The empirical study of intelligence-based composition strategies and individual learning can be found across several literatures, including research on teams from industrial and organizational psychology, classroom composition from education and educational psychology, and scaffolding approaches from educational and developmental psychology. In the literature on teams, only few studies have manipulated the ability composition of teams and compared the influence of heterogeneous versus homogeneous compositions on resulting individual performance. For example, Dossett and Hulvershorn (1983) demonstrated that ability-based pairing strategies affected the efficiency of Air Force technical training using computer-assisted instruction. Specifically, they noted that, for high-ability trainees, heterogeneous pairing strategies increased the amount of time needed to complete training, but, for low-ability trainees, heterogeneous pairings did not affect training time. In a study involving military paramedical training, Brooks, Ebner, Manning, and Balson (1985) found that heterogeneous pairings were beneficial to low-ability members of a learning dyad but deleterious to high-ability members.

Although few studies have examined the ability composition of training teams using an experimental design, the growing literature on cooperative learning strategies in elementary and secondary education can offer insight into the optimal ability compositions of training teams (see Hooper, 1992; Hooper, Temiyakarn, & Williams, 1993; Webb, Nemer, Chizhik, & Sugrue, 1998). Advocates of mixed-ability groupings claim that, along with its potential positive affective consequences, mixed-ability groupings also have important positive cognitive consequences (Slavin, 1990), especially when tutor–tutee relationships exist among group members (Webb, 1982a, 1982b). The contention is that high–low pairings result in favorable outcomes for both high- and low-ability students. However, skeptics suggest that heterogeneous groupings fail to challenge high-ability students (Willis, 1990) and that less able students benefit at the expense of their more able partners (Mills & Durden, 1992; Robinson, 1990).

Consistent with the mixed opinions regarding the relative superiority of heterogeneous versus homogeneous teams, the empirical research offers mixed findings, with some studies indicating that heterogeneous groupings lead to better achievement for both low- and high-ability students (e.g., Beane & Lemke, 1971; Larson et al., 1984; Webb, 1980), and other studies indicating that low-ability students benefit from heterogeneous groupings, while the achievement of high-ability students suffers (Dar & Resh, 1986; Hooper & Hannafin, 1988; Webb et al., 1998). With respect to heterogeneous groupings, researchers have also suggested that the benefits for low-ability students are significantly larger than the losses incurred by high-ability students (Dar & Resh, 1986; Webb et al., 1998). In fact, recent meta-analyses of field studies in cooperative learning (Lou, Abrami, & Spence, 2000; Lou et al., 1996) have shown that the achievement of low-ability students increases by approximately one-half a standard deviation in heterogeneous groupings compared to homogeneous groupings, while the achievement of high-ability students is not differentially influenced by composition strategy.

However, recent research has also suggested that the effects of cooperative learning may be moderated by the age of the learner and task complexity. First, the effects of cooperative learning may be smaller in adult populations (Lou et al., 2000). Second, for complex tasks, low-ability learners may not benefit from heterogeneous groupings, and high-ability learners may learn less when placed with low-ability partners instead of high-ability partners (Fuchs, Fuchs, Hamlett, & Karns, 1998). The difference in results for complex tasks may stem from the quality of interactions that take place between partners during training. Higher-level learning in a team or group context is dependent on an equally high level of discourse among team members (King, 1999). For instance, homogeneous pairings for high-ability individuals may foster cognitive collaboration, including sharing creative solutions, discussing alternatives, and resolving differences in ideas. Within heterogeneous pairings, cognitive collaboration may be stifled with low-ability individuals sometimes confusing high-ability partners and high-ability individuals having difficulty explaining task complexities to low-ability partners (Fuchs et al., 1998).

Similar inferences have been made in the literature on scaffolding. Scaffolding refers to a variety of instructional approaches that involve collaboration and providing just enough assistance to extend the learner's current capabilities. Assistance could come in the form of providing hints or asking probing questions, but, generally, scaffolding refers to modeling advanced response patterns that are within the reach of the learner's current capabilities. The roots of scaffolding can be found in developmental psychology and traced specifically to Vygotsky's (1978, 1987) concept of the zone of proximal development (ZPD), which refers to "the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (p. 86).

Perhaps more so than any other concept in the psychological literature, ZPD addresses the role of intelligence at the junction of the individual and interindividual levels. Vygotsky emphasized the interindividual determinants of individual functioning and specified that potential is not determined solely by an individual's ability (Valsiner & Van der Veer, 1999; Wertsch, 1999). With the help of more capable others, individuals can function at more advanced levels than they are capable of independently, which in turn affords individuals the opportunity to practice and internalize qualitatively advanced aspects of thinking and skill (Tudge, 1990).

With respect to scaffolding through peer learning, parallel participation (i.e., simply performing alongside one another) is not sufficient to scaffold an individual's development. Rather, scaffolding, and consequently development, occurs when peers function in a coordinated manner through a joint understanding of the situation (Hogan & Tudge, 1999). Joint understanding is referred to as intersubjectivity in the ZPD literature and is considered a critical process to development. If assistance is too far advanced or out of the reach of the individual's present capabilities, then intersubjectivity is not likely to occur. With the criticality of intersubjectivity in mind, it is commonly recommended that the distance between collaborators' level of competence not be great.

The implications of intersubjectivity for ability-based pairing strategies is that learning complex and difficult tasks will be optimal when there are only small differences between partners' levels of intelligence. In other words, benefits are not likely to occur when low-ability individuals are paired with high-ability partners. Moreover, consistent with Laughlin and Johnson (1966), the redundancy in cognitive resources within mixed-ability pairs is not likely to lead to substantial gains in team or group performance relative to the individual performance of high-ability individuals. A common interpretation of ZPD is that no individual gains should be expected from collaboration if collaborative performance is not greater than individual performance (Chaiklin, 2003). Thus, high- and low-ability individuals are not likely to benefit from mixed-ability pairings because neither gains insight into advanced forms of understanding and performing the task at hand. The high-ability individual is simply not exposed to more advanced forms of performance, and the low-ability individual cannot understand the more advanced forms of performance.

5. Study overview and hypotheses

Continued research that relates team composition manipulations of intelligence to team performance and individual learning is needed to better understand how the effects of intelligence at the interindividual level influence individual behavior. The existing literature is limited in two respects. Researchers have not manipulated the intelligence composition of teams and simultaneously examined team and individual performance where the same participants performed in teams and as individuals. This has precluded researchers from examining how intelligence in interindividual contexts affects individual learning vis-à-vis team performance. Furthermore, the empirical literature on collaborative and peer learning has been limited mostly to children using relatively simple tasks. Research involving samples from the adult population using complex tasks is needed. Therefore, the purpose of the present study was to investigate the relationship between intelligence and the effectiveness of dyadic training teams by creating homogeneous high-ability, homogeneous low-ability, and mixed-ability teams on the basis of intelligence. There were 12 training sessions spread over a 2-week period. Training sessions were divided into three components: participants practiced together in teams, participants were tested performing the task as a team, and participants were tested performing the task individually. To examine the interplay of the effects of intelligence in interindividual and individual contexts, we tested a number of team- and individual-level hypotheses. Below, we review the study's primary hypotheses. Table 1 formally presents these hypotheses as well as several secondary hypotheses. Table 1 also provides a summary of how the data from the present study supported the hypotheses.

Given that it has been well established that intelligence is a valid predictor of individual skill acquisition (Fleishman & Mumford, 1989; Ree & Earles, 1991) and team performance (Devine & Philips, 2001), we hypothesized an additive effect of intelligence such that intelligence would be positively related to team and individual performance scores. We also expected the effects of ability at the team level to transfer to individuals. Thus, we hypothesized that individual performance would be a function of the teams to which they were assigned in training; specifically, we expected individual skill acquisition to be correlated with team performance. We also expected nonadditive effects of intelligence

Table 1
Research hypotheses

Hypothesis	Support
1. Intelligence will be positively related to performance. Uniformly high-ability teams will have higher team performance scores than mixed-ability teams, who in turn will have higher team performance scores than uniformly low-ability teams. High-ability trainees will achieve higher individual performance scores than low-ability trainees.	Yes
2. Individual performance scores will be a function of the training teams to which trainees are assigned; specifically, in a given training session, team performance will be positively related with individual performance even when controlling for individual performance scores from earlier training sessions.	Yes
3. The difference in team performance scores between uniformly high-ability teams and mixed-ability teams will be greater than the difference between mixed-ability teams and uniformly low-ability teams.	Partial
4. High-ability individuals who train with high-ability partners will achieve higher individual performance scores than high-ability individuals who train with low-ability partners.	Yes
5. Low-ability individuals who train with high-ability partners will not have higher levels of individual performance compared to low-ability individuals who train with low-ability partners.	Yes
6. Individuals who train in mixed-ability teams will rate the quality of communication in their teams lower compared to trainees in homogeneous teams.	No
7. Low-ability individuals who train with high-ability partners will rate their partners stronger in leadership than other trainees.	Yes
8. High-ability individuals who train with low-ability partners will rate themselves stronger in leadership than other trainees.	No
9. High-ability individuals who train with low-ability partners will rate the degree of cohesion in their dyads lower compared to other trainees.	Yes
10. The communication–performance relationship will be stronger for low-ability individuals who train with high-ability partners than for all other trainees.	Yes
11. Ratings of leadership will be differentially related to individual performance for trainees from mixed-ability team than for all other trainees.	No

Support—the extent to which the present study's data supported the hypothesis.

at both team and individual levels. Based on the positive nonadditive effects associated with homogeneous high-ability teams shown previously in the literature (e.g., Laughlin & Johnson, 1966; Tziner & Eden, 1985), we hypothesized that the difference in team performance scores between uniformly high-ability teams and mixed-ability teams would be greater than the difference between mixed-ability teams and uniformly low-ability teams. Regarding nonadditive effects at the individual level, we hypothesized that high-ability individuals who train with high-ability partners would achieve higher individual performance scores than high-ability individuals who train with low-ability partners, whereas low-ability individuals who train with high-ability partners would not have higher levels of individual performance compared to low-ability individuals who train with low-ability partners. This difference in predicted effects for high- and low-ability individuals is consistent with Fuchs et al.'s (1998) research on the cooperative learning of difficult tasks and suppositions from the ZPD literature (e.g., Hogan & Tudge, 1999; Wertsch, 1999).

We were also interested in how the ability composition of training teams affects the nature of team member interactions and how these interactions during team training are related to individual skill acquisition. Specifically, we expected individual perceptions of communication, leadership, and cohesion to differ as a function of team composition. In particular, we were interested in contrasting individual perceptions found in members of mixed-ability training teams to those found in homogeneous teams. We expected low communication ratings in mixed-ability teams. We also expected to find differences in perceived leadership in mixed-ability teams compared to homogeneous teams. In contrast to homogeneous teams, differences in individual competency should be readily apparent among mixed-ability teams, with high-ability partners gaining more expert power (French & Raven, 1959) than low-ability partners. Subsequently, high-ability individuals would be more likely to emerge as leaders in training teams than low-ability individuals. Consistent with social exchange models of attraction (Thibaut & Kelley, 1959), we posited that high-ability individuals who train with low-ability partners would find working in dyadic teams the least rewarding and would subsequently experience the least cohesion in their teams. High-ability trainees working in mixed-ability teams may even become annoyed or angered by their less capable partners (Secord & Backham, 1974) and feel exploited because their low-ability partners are not able to reciprocate in providing task-related insight (Gordon, 1997). We therefore expected high-ability individuals who trained with low-ability partners to rate the degree of cohesion in their dyads lower compared to other trainees.

In general, we expected positive relationships between individual skill acquisition and ratings of communication, leadership, and cohesion. We were particularly interested in the strength of the relationships found in the mixed-ability teams for communication and leadership. The willingness of high-ability partners to exchange information and provide clear explanations would be critical to the successful improvement of task understanding and skill for low-ability trainees. Learning for low-ability trainees would also depend on their willingness to seek advice, clarification, and direction from their higher-ability partners. Therefore, we expected that the communication–performance relationship would be stronger for low-ability individuals from mixed-ability teams than for all other trainees. Likewise, it would be important for high-ability individuals to take charge of the training situation to ensure that their lower-ability partners did not unduly hinder their team's progress or their own skill development. Thus, compared to trainees from homogeneous teams, we expected differences in the magnitude of correlations between ratings of leadership and individual performance from mixed-ability trainees.

The performance task used in the present study was the video game Space Fortress (Donchin, 1989; Mane & Donchin, 1989). Space Fortress is "an experimental game which was designed to simulate a complex and dynamic aviation environment" (Gopher, 1993, p. 299). Space Fortress represents important information processing demands that are present in aviation and other complex tasks (Gopher, Weil, & Bareket, 1994; Hart & Battiste, 1992). These processing demands include short- and long-term memory loading, high workload, dynamic attention allocation, decision-making, prioritization, resource management, discrete motor responses, and difficult manual control elements (Gopher, Weil, & Siegel, 1989). There are several reasons why Space Fortress is an appropriate task for studying the interplay of the effects of intelligence at interindividual and individual levels. First, previous empirical studies have demonstrated that the acquisition of Space Fortress skill is correlated with intelligence test scores (Day, Arthur, & Shebilske, 1997; Rabbit, Banerji, & Szymanski, 1989). Second, although originally designed for studying individual skill acquisition, the performance components to Space Fortress can be divided into pilot and copilot functions. This allows researchers to study team performance as well as individual skill acquisition (Shebilske, Goettl, & Regian, 1999). Third, Space Fortress components are highly interdependent such that successful overall performance requires the proper coordination and effective performance of all components. This interdependence is important in studying intelligence at an interindividual level because it requires training partners to actually collaborate when learning and performing together rather than simply performing alongside each other without communication and coordination. Using Space Fortress and having individuals practice and perform jointly as well as test individually throughout training allowed us to examine the effects of intelligence on both team performance and individual skill acquisition. More importantly, we were able to examine the interplay between the individual and interindividual levels by modeling the effects of partner intelligence and team performance on individual skill acquisition.

6. Method

6.1. Participants

An initial sample of 1266 male volunteers from Texas A&M University was recruited using advertisements in the university newspaper, announcements in classrooms, and posted notices around campus. Participants were required to be at least 18 years of age. Furthermore, due to hardware constraints, only right-handed volunteers could participate in the study. Of 1266 individuals screened, 194 were selected on the basis of their intelligence scores. Eighteen of the selected participants did not complete the study, resulting in an attrition rate of 9%. Chi-squares indicated no differences in attrition across the three levels of team ability. As a result of screening and attrition from the study, the final sample size was 176, which translated into 88 training dyads (i.e., 29 HH, 32 HL, and 27 LL dyads). The mean age of the final sample was 19.62 (S.D.=2.30). Participants who completed the study were paid $75, and participants who were not selected were paid $5 for the screening session. Participants also competed for bonuses of $100, $60, and $40, which were awarded to the top three performing teams.

6.2. Measures

6.2.1. Raven's Advanced Progressive Matrices (APM; Raven, Raven, & Court, 1998)

The APM is a measure of general intelligence that consists of 36 matrix problems arranged in an ascending order of difficulty. The APM is scored by summing the number of problems correctly answered. We used an administration time of 40 min. The test manual reports a test–retest reliability of 0.91 for the APM scores. We obtained a Spearman–Brown odd–even split-half reliability of 0.84. Scores on the APM were used to select participants into the study and also to create the different ability pairings.

6.2.2. *Space Fortress (Mane & Donchin, 1989)*

Laboratory rooms were equipped with a table, a computer and monitor, a right-hand joystick, a three-button mouse for the left hand, and two right-handed chair desks. In Space Fortress, trainees control a space ship's flight path using the joystick and shoot missiles with a trigger on the joystick. A fortress is located center screen, with two concentric hexagons surrounding it. An information panel at the bottom of the screen indicates fortress vulnerability, which changes with each missile hit. Friend and foe mines fly in the space surrounding the fortress and are identified by a mine indicator on the information panel. To destroy foe mines, trainees are required to push an "identify friend or foe" mouse button at the appropriate time. Symbols appear on the screen just below the fortress to indicate opportunities to gain bonus points or additional missiles by pushing either a "points" or "missiles" mouse button at the appropriate time. Furthermore, the information panel shows the number of available missiles, a battle score, and component scores based on ship velocity, ship control, and the speed of dispatching mines. The screen displays a total score, which is a composite of the others, along with more detailed performance feedback at the end of each game.

6.2.3. *Perceptions of team interactions*

We developed a 13-item paper-and-pencil instrument to measure individual perceptions of the interactions that took place within dyadic training teams. We selected and adapted the items from previous instruments (i.e., Barry & Stewart, 1997; Morgan, Glickman, Woodard, Blaiwes, & Salas, 1986) to assess communication (four items), leadership (two items), and sense of cohesion (seven items). Trainees were instructed to rate the extent to which each item was descriptive of himself and his partner with respect to their interactions as a team. Thus, each trainee made separate responses for himself and his partner. Responses to all the items were made on a five-point scale (1: to a very little extent; 5: to a very great extent). Communication items included "has a chance to express opinions" and "listens to the other's input." The leadership items included "assumes a leadership role" and "acts as team leader." Cohesion items included "has a feeling of unity and cohesion within the team" and "works well with partner." The instrument was administered on four separate occasions during training. The average coefficient alpha for the self-ratings was 0.71 for communication, 0.91 for leadership, and 0.92 for cohesion. The average coefficient alpha for the partner-ratings was 0.70 for communication, 0.89 for leadership, and 0.92 for cohesion. Across the four administrations and both ratings of self and partner, the average correlation between different administrations of the same scale (i.e., test–retest reliabilities) was 0.58 for communication, 0.71 for leadership, and 0.69 for cohesion.

6.3. *Design and procedure*

Performance on the APM was used to select participants into the study and also to create the different ability groups. Individuals were retained if they scored 21 or lower or 27 or higher on the APM. These cut-off scores represented 1 standard error of measurement (S.E.M.) above and below the mean APM score based on a sample (n=496) consisting of 363 participants who completed the APM for a prior study (Arthur & Woehr, 1993) and 133 participants comprising the first screening group for the present study. Using this approach ensured that the low- and high-ability participants would indeed be categorically different.

Following screening, three sets of training teams were created on the basis of the participants' intelligence scores. Teams were composed of dyads who were both high (HH), both low (LL), or mixed (HL) in terms of their intelligence. Assignment of partners was random within ability level, and trainees were assigned to the same partner throughout training.

After selection, trainees participated in 10 days of training extended over 2 weeks. On the Monday of the first week, trainees began with 20 min of videotaped instructions that explained the rules of Space Fortress. They were also informed of four strategies on how to perform Space Fortress (Frederiksen & White, 1989). Trainees then performed two team and two individual 3-min games of Space Fortress (session 1). This was followed by a 5-min review video of the instructions and strategies. Following this review, trainees underwent 11 more Space Fortress training sessions that took place over the next 13 days. Trainees completed the team interaction scales after sessions 2, 5, 7, and 12.

During a standard training session, dyadic teams performed six practice games together followed by two team test games. Trainees were informed that the monetary bonuses would be determined by their scores on the team test games, but their individual performance would also be evaluated. Hence, after the two team test games, trainees also completed two individual test games. All games lasted 3 min. When performing as a team, trainees performed with their partner—one trainee, using his left hand, controlled all functions related to the mouse (copilot mine–missile manager), and the other trainee, using his right hand, controlled all functions related to the joystick and trigger (pilot–gunner). Trainees alternated roles, which called for physically switching places at the end of each game. Communication between trainees was encouraged. Trainees controlled both the mouse and joystick functions when performing their individual test games. A typical training and testing session lasted approximately 1 h, and trainees were scheduled to train at the same 1-h slot for their 2 weeks of participation. For each session, team performance was operationalized as the mean of the total scores from the pair of team test games; likewise, individual performance was operationalized using the mean from the pair of individual test games.

7. Results

7.1. APM scores

The mean APM score for the entire sample of trainees was 24.16 (S.D.=6.43). As previously mentioned, we used cut-off scores of not higher than 21 for the low-ability grouping and not lower than 27 for the high-ability grouping. The mean APM score of low-ability trainees was 18.14 (S.D.=2.78), and the mean APM score of high-ability trainees was 29.91 (S.D.=2.32.). Comparing these values to previously established norms should be done with caution considering the APM normative data for the United States are inadequate (McCallum, Bracken, & Wasserman, 2001). Indeed, the manual for the APM (Raven et al., 1998) does not report norms for a sample of college students from the United States using an administration time of 40 min. The most relevant normative data reported come from a sample of 639 college graduates who applied to an Australian Public Service training program in the late 1980s. Relative to this normative sample, the cut-off and mean APM scores for our low-ability trainees

Table 2
Dispersion of APM scores within teams

Team ability composition	M	S.D.	Minimum	Maximum
HH	2.48	1.66	0	7
HL	12.09	3.96	7	20
LL	2.78	2.39	0	9
Overall	6.07	5.40	0	20

Dispersion is the absolute value of the difference between partner APM scores. HH—two high-ability teammates (n=29 teams). HL—one high-ability and one low-ability teammate (n=32 teams). LL—two low-ability teammates (n=27 teams).

represent the 37th and 22nd percentiles, respectively. For our high-ability trainees, the cut-off and mean APM scores represent the 83rd and 93rd percentiles, respectively. Over the last 4 years, we have collected data on a sample of 237 college students from two large public universities in the United States—one from the Midwest and another from the Southwest. Neither university is the same university in which the present study was conducted. The mean APM score for this normative sample was 24.52 (S.D.=5.72). Relative to this normative sample, the cut-off and mean APM scores for our low-ability trainees represent the 26th and 15th percentiles, respectively. For our high-ability trainees, the cut-off and mean APM scores represent the 68th and 86th percentiles, respectively. Overall, we believe that our low-ability and high-ability samples represent extremes in the distribution of intelligence scores with respect to a college student population. Because intelligence scores tend to be higher in college samples compared to noncollege samples, our high-ability sample likely represents a more extreme group, whereas our low-ability sample likely represents a less extreme group, relative to the general population.

Table 2 shows the dispersion of APM scores within teams. As a direct indicator of their homogeneity, training partners in both the high- (dispersion M=2.48) and low-ability (dispersion M=2.78) teams were substantially more similar in their APM scores compared to partners in the mixed-ability teams (dispersion M=12.09). Although these results also indicate variability in APM scores within homogeneous teams, the variability was substantially smaller compared to mixed-ability teams. In fact, the majority of homogeneous teams had dispersion scores within 1 S.E.M. In sum, the individual- and team-level descriptive statistics show that, in sharp contrast to the large differences in intelligence between partners from mixed-ability teams, the high- and low-ability teams were indeed homogenous with respect to intelligence.

7.2. Additive effects

7.2.1. Team level

Table 3 presents the descriptive statistics for team performance for each ability condition. A 3 (ability composition: LL, HL, or HH)$\times$12 (sessions 1 through 12) mixed analysis of variance (ANOVA) revealed a statistically significant between-subjects main effect for ability composition on team performance, $F(2, 85)=13.39$, $p<0.001$, $\eta^2=0.24$. The mean team test performance was 1243.80 (S.D.=1155.77), 1905.28 (S.D.=1346.63), and 2925.17 (S.D.=1154.34) for LL, HL, and HH teams, respectively. In support of Hypothesis 1, higher team ability was associated with higher team performance. The results also indicated a statistically significant within-subjects main effect, $F(11, 935)=407.09$, $p<0.001$, $\eta^2=0.83$. Team performance improved across training sessions. In addition, the results revealed a statistically significant interaction between ability composition and training session,

Table 3
Means and standard deviations of team performance across sessions and by ability composition

SF team test performance	Ability composition					
	HH		HL		LL	
	M	S.D.	*M*	S.D.	*M*	S.D.
Session 1	−1478.19	705.03	−2137.36	665.29	−1888.89	679.28
Session 2	869.43	1173.40	154.81	1126.36	−55.63	863.82
Session 3	1907.64	1360.88	1010.33	1229.46	416.25	1061.19
Session 4	2801.21	1307.74	1688.28	1614.51	977.36	1049.31
Session 5	3001.02	1277.08	1815.81	1515.11	1098.53	1019.42
Session 6	3337.86	1332.56	2126.53	1509.61	1385.68	1319.38
Session 7	3644.97	1393.49	2451.45	1718.82	1668.04	1336.10
Session 8	3969.28	1341.68	2766.16	1578.89	1912.46	1679.18
Session 9	4039.14	1570.89	2970.35	1911.75	2014.51	1870.45
Session 10	4185.19	1394.19	3211.98	1644.86	2520.01	1671.98
Session 11	4346.07	1358.84	3304.11	1633.58	2487.74	1517.71
Session 12	4478.38	1319.64	3500.89	1641.85	2389.50	1793.44
Mean	2925.17	1154.34	1905.28	1346.63	1243.80	115.77

SF—Space Fortress. HH—two high-ability teammates (n=29 teams). HL—one high-ability and one low-ability teammate (n=32 teams). LL—two low-ability teammates (n=27 teams).

$F(11, 935)=3.87, p<0.001, \eta^2=0.08$. Consistent with Hypothesis 1, higher-ability teams achieved higher levels of performance at a faster rate than lower-ability teams.

7.2.2. Individual level

For the analyses involving individual skill acquisition, we divided the mixed-ability teams into two conditions—those where a high-ability trainee was paired with a low-ability trainee (H_L) and those where a low-ability trainee was paired with a high-ability trainee (L_H)—yielding four different conditions (H_H, H_L, L_H, and L_L). Table 4 presents the descriptive statistics for individual performance. Because individuals were nested in dyadic teams, we used the SAS MIXED procedure (SAS Institute, 1999) to examine the skill acquisition effects at the individual level and treated dyadic team as a random effects variable. Indeed, the results revealed a statistically significant effect for dyadic team (z=4.73, p<0.001), supporting Hypothesis 2 and indicating that our individual participants should be treated as nested within their respective dyadic teams. We expected that the team effect would largely stem from differences in team performance. To examine this effect directly, for each training session, we computed the partial correlation between team performance scores and individual performance scores controlling for the effects of individual performance scores from the previous session. Because of the nonindependence of the individual data, we randomly chose one participant from each team for these analyses. Across sessions, the mean partial correlation was 0.42 (p<0.001), with a minimum of 0.27 and maximum of 0.57. These results support Hypothesis 2 and show a strong effect of team performance on individual skill acquisition.

We then examined fixed effects for individual ability (high versus low), partner ability (high versus low), session (1 through 12), and all corresponding interactions. The results indicated a statistically significant between-subjects main effect for individual ability, $F(1, 116)=28.99$, $p<0.001$, $\eta^2=0.20$. In support of Hypothesis 1, at the individual level, high-ability trainees acquired more skill than low-ability

Table 4
Means and standard deviations of individual performance across sessions and by partner assignment

SF individual test performance	Partner assignment							
	H_H		H_L		L_H		L_L	
	M	S.D.	*M*	S.D.	*M*	S.D.	*M*	S.D.
Session 1	−841.60	1196.68	−1501.61	1394.85	−1748.95	904.55	−1506.26	1295.95
Session 2	775.53	1166.64	321.60	1257.74	−304.31	1397.28	−409.36	1267.87
Session 3	1556.82	1505.88	1016.45	1432.08	348.77	1379.43	216.94	1130.54
Session 4	2370.56	1520.64	1708.64	1730.89	687.54	1414.99	609.07	1430.56
Session 5	2564.33	1535.08	1910.72	1643.48	1118.94	1733.55	914.10	1438.70
Session 6	2875.57	1538.97	2188.61	1573.43	1307.23	1801.91	971.47	1578.63
Session 7	3051.59	1645.26	2307.23	1648.33	1769.84	1777.65	1352.47	1637.17
Session 8	3435.66	1567.78	2864.52	1683.76	1976.02	1963.32	1687.06	1813.27
Session 9	3560.53	1662.76	2905.08	1775.33	2009.02	1939.89	1604.05	1908.16
Session 10	3931.40	1505.04	3252.95	1626.09	2445.02	1886.57	2168.77	1829.86
Session 11	3940.98	1534.43	3367.08	1612.87	2415.84	1847.45	2082.86	1926.90
Session 12	4112.22	1512.72	3454.48	1572.76	2641.69	2032.11	2163.87	1924.05
Mean	2611.13	1309.53	1982.98	1352.52	1224.55	1525.30	987.92	1414.12

SF—Space Fortress. H_H—high-ability trainees assigned to high-ability partners (n=58). H_L—high-ability trainees assigned to low-ability partners (n=32). L_H—low-ability trainees assigned to high-ability partners (n=32). L_L—low-ability trainees assigned to low-ability partners (n=54).

trainees (d=0.83). Results also indicated a statistically significant between-subjects main effect for partner ability, $F(1, 116)=3.82$, $p=0.05$, $\eta^2=0.03$. Trainees with high-ability partners acquired more skill than trainees with low-ability partners (d=0.30). The results of the within-subjects main effect indicated that trainees' performance improved across training sessions, $F(11, 1948)=139.71$, $p<0.001$, $\eta^2=0.44$. Additionally, the results revealed a statistically significant interaction between individual ability and training session, $F(11, 1948)=3.72$, $p<0.001$, $\eta^2=0.02$. Consistent with Hypothesis 1, high-ability trainees achieved higher levels of performance at a faster rate than low-ability trainees.

7.3. Nonadditive effects

7.3.1. Team level

The team performance means were consistent with Hypothesis 3—the difference between HH teams and HL teams ($t(59)=3.16$, $p<0.01$, $d=0.81$) was greater than the difference between HL and LL teams ($t(57)=2.00$, $p<0.05$, $d=0.52$). However, the results of a direct comparison of these differences did not reach conventional levels of statistical significance, $z=1.41$, $p<0.08$ (one-tailed), offering only mixed support for Hypothesis 3.

7.3.2. Individual level

Although the SAS MIXED procedure did not reveal an interaction between individual ability and partner ability, $F(1, 116)=0.78$, $p=0.38$, we conducted planned comparisons to more closely examine the nonadditive effects we predicted in Hypotheses 4 and 5. Accordingly, we conducted two separate sets of analyses and compared H_H to H_L trainees and L_H to L_L trainees (taking into account the random effect of dyadic team). Table 5 shows the results of these comparisons. In support of both hypotheses and

Table 5
Partner effects as a function of trainee ability

SF individual test performance	H_H versus H_L		L_H versus L_L	
	t	*d*	*t*	*d*
Session 1	2.36*	0.50	−0.83	−0.20
Session 2	1.64	0.37	0.36	0.08
Session 3	1.56	0.35	0.48	0.10
Session 4	1.75**	0.40	0.24	0.05
Session 5	1.75**	0.40	0.57	0.13
Session 6	1.84**	0.43	0.88	0.20
Session 7	1.91**	0.44	1.09	0.24
Session 8	1.48	0.34	0.66	0.15
Session 9	1.56	0.37	0.88	0.21
Session 10	1.79**	0.42	0.62	0.15
Session 11	1.50	0.36	0.73	0.17
Session 12	1.76**	0.42	0.98	0.24
Mean across sessions	1.96**	0.47	0.69	0.16

SF—Space Fortress. H_H versus H_L—high-ability trainees assigned to high-ability partners compared to high-ability trainees assigned to low-ability partners. L_H versus L_L—low-ability trainees assigned to high-ability partners compared to low-ability trainees assigned to low-ability partners. *t*—independent *t* test comparing trainees of similar ability levels but whose partners differed on ability; values for *t* are based on the results when accounting for the random effect of the dyadic team. *d*—standardized mean difference between conditions. All significance tests are one-tailed.

* $p<0.01$.

** $p<0.05$.

demonstrating nonadditive effects of partner ability, an overall statistically significant difference in skill acquisition was observed between H_H and H_L trainees (d=0.47), but the overall difference between L_H and L_L trainees was not statistically significant (d=0.16).

7.4. Team versus individual performance

To facilitate comparisons between team and individual performance, we plotted both team and individual tests scores on the same graph. This graph is displayed in Fig. 1. As shown, it appears that the results did not consistently support the old adage "two heads are better than one." In particular, the performance of mixed-ability teams across test sessions was not higher than the individual performance of high-ability trainees from those same mixed-ability teams (d=−0.06). Low-ability teams, in slight contrast, did outperform their individual counterparts, but the differences across test sessions was small (d=0.16). The effects for high-ability teams were more favorable regarding the performance gains of teams over individuals. Specifically, the performance of high-ability teams across test sessions was higher than the individual performance of trainees from those same high-ability teams (d=0.25). Overall, these results demonstrated that no benefits were accrued by pairing low-ability partners with high-ability individuals. Specifically, no gain was made to team performance in this pairing strategy. Not only were the high-ability trainees from these teams able to perform just as well by themselves as with their partners, but also the performance of these teams across test sessions was lower than the individual performance of high-ability trainees who trained in homogenous teams (d=−0.53).

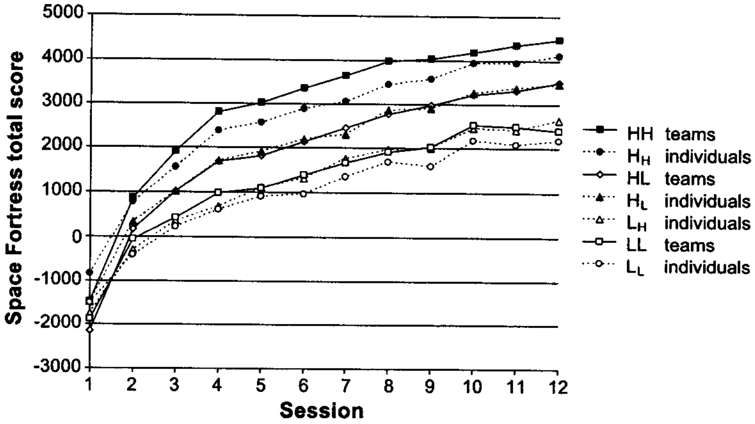

Fig. 1. Mean Space Fortress test scores for both teams and individual trainees. Teams: HH—two high-ability teammates; HL—one high-ability and one low-ability teammate; and LL—two low-ability teammates. Individuals: H_H—high-ability trainees assigned to high-ability partners; H_L—high-ability trainees assigned to low-ability partners; L_H—low-ability trainees assigned to high-ability partners; and L_L—low-ability trainees assigned to low-ability partners.

7.5. *Individual perceptions of team interactions*

Data for the team interaction variables were incomplete for six participants. Therefore, these participants were omitted from the following analyses. Correlations between self- and partner-ratings were very strong for communication (r=0.91) and cohesion (r=0.94), but the correlation between self- and partner-ratings was moderate for leadership (r=0.39). The average correlation between scales was 0.44 for trainee self-ratings and 0.41 for partner-ratings. The correlations between perceptions of team interactions and individual performance varied by training condition (i.e., partner assignments). Therefore, we present the correlations between average individual performance and all the team interaction variables for each of the four training conditions in Table 6. Fig. 2 shows the means for the team interaction variables for each training condition.

Table 6
Correlations between average training performance and team interactions by partner assignment

Variable	H_H	H_L	L_H	L_L
Communication—self	0.22*	0.07	0.43**	−0.07
Communication—partner	0.19	0.14	0.46**	−0.10
Leadership—self	0.27**	0.43**	0.12	0.06
Leadership—partner	0.00	0.07	−0.06	−0.35**
Cohesion—self	0.25*	0.25	0.34*	−0.12
Cohesion—partner	0.35***	0.25	0.24	−0.08

H_H—high-ability trainees assigned to high-ability partners (n=58). H_L—high-ability trainees assigned to low-ability partners (n=31). L_H—low-ability trainees assigned to high-ability partners (n=31). L_L—low-ability trainees assigned to low-ability partners (n=50). All significance tests are two-tailed.

* $p<0.10$.

** $p<0.05$.

*** $p<0.01$.

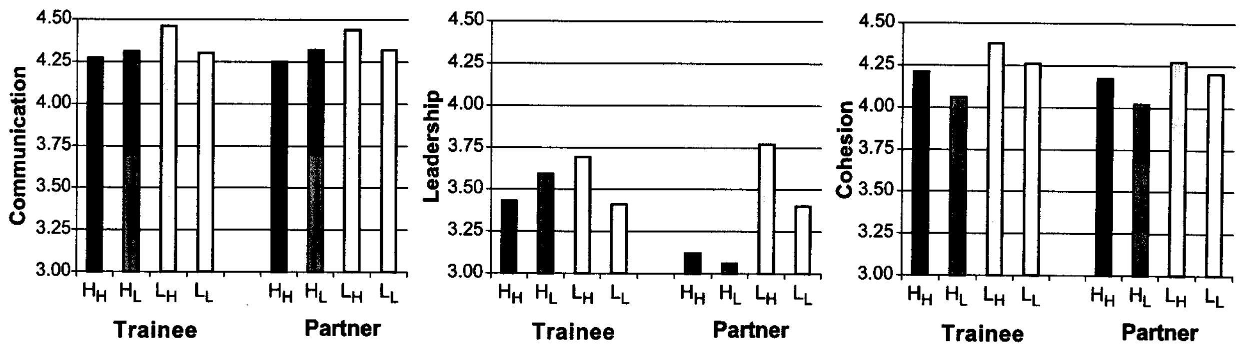

Fig. 2. Mean interaction ratings of trainees (i.e., self-ratings) and partners as a function of trainee and partner ability. H_H—high-ability trainees assigned to high-ability partners. H_L—high-ability trainees assigned to low-ability partners. L_H—low-ability trainees assigned to high-ability partners. L_L—low-ability trainees assigned to low-ability partners.

7.5.1. Effects of partner assignments

To address Hypotheses 6 through 9, we used the SAS MIXED procedure and treated dyadic team as a random effects variable. We then examined fixed effects for individual ability (high versus low), partner ability (high versus low), target of ratings (self versus partner), and all corresponding interactions. Because we had no theoretical reason to expect differences to vary across administrations, we collapsed the team interaction data across the four separate administrations.

Although the results revealed a statistically significant random effect for dyadic team (z=5.49, p<0.001), no other statistically significant effects were found for communication. Contrary to Hypothesis 6, a planned comparison did not indicate lower ratings of communication from trainees in mixed-ability teams compared to trainees from homogeneous teams. In fact, trainees across all conditions reported fairly high levels of communication (all means were greater than 4.24), with H_L and L_H trainees reporting slightly higher levels than other trainees.

In contrast to the ratings made for communication, the means for leadership varied across conditions and were generally much lower (all means were less than 3.80). The results revealed a statistically significant random effect for dyadic team, z=2.62, p<0.001. A between-subjects main effect indicated that low-ability trainees reported higher levels of leadership within their dyads compared to high-ability trainees, $F(1, 114)=6.41$, $p<0.05$, $\eta^2=0.05$. A within-subjects main effect indicated that self-ratings of leadership were higher than partner-ratings, $F(1, 219)=5.34$, $p<0.05$, $\eta^2=0.02$. However, these main effects were qualified by a statistically significant interaction between target and individual ability, $F(1, 219)=7.73$, $p<0.01$, $\eta^2=0.03$. Although low-ability trainees in general did not rate themselves differently on leadership compared to high-ability trainees, low-ability trainees reported higher levels of leadership for their partners compared to high-ability trainees. Specifically, and in support of Hypothesis 7, L_H trainees reported higher levels of leadership in their partners compared to all other trainees, $t(114)=4.03$, $p<0.001$, $d=0.72$. In contrast, Hypothesis 8 was not supported—H_L trainees did not rate themselves higher on leadership compared to other trainees. No other statistically significant effects were observed for leadership.

Similar to the results for communication, ratings of cohesion within teams were fairly high across training conditions (all means were greater than 4.00). The results revealed a statistically significant random effect for dyadic team, z=5.89, p<0.001. Although the exploratory analysis did not reveal any statistically significant effects, the results of a planned comparison supported Hypothesis 9, indicating that H_L trainees rated the cohesion in their teams lower compared to other trainees, $t(114)=-2.03$, $p<0.05$, $d=-0.36$.

7.5.2. Correlations with individual performance

As shown in Table 6, the correlations between perceptions of team interactions and individual training performance varied across the different partner assignments. In support of Hypothesis 10, the correlations between communication and performance were stronger for H_L trainees than for other trainees. To test the statistical significance of these differences, we collapsed self- and partner-ratings into a single index of communication and then compared the correlation for H_L trainees to the average of the correlations across the remaining conditions. The results indicated that the difference in communication–performance correlations was statistically significant, z=1.95, p<0.05, one-tailed. In contrast, the results did not support Hypothesis 11. That is, the correlation between self-ratings of leadership and performance for H_L trainees was not significantly larger than the correlations across the other training conditions, and the correlation between partner-ratings of leadership and performance for L_H trainees was not significantly larger than the correlations for other trainees. In fact, contrary to our prediction, the correlation between partner-ratings of leadership and performance was statistically significant and negative for L_L trainees in contrast to the other training conditions, $z=-2.12, p<0.05$. Lastly, the results also indicated that cohesion was positively related to performance across the training conditions, with the exception of L_L trainees, $z=2.25, p<0.05$.

8. Discussion

The purpose of the present study was to investigate the interplay of the effects of intelligence across individual and interinterindividual levels by manipulating the intelligence-based composition of dyadic training teams and by examining both team performance and individual skill acquisition. At the dyadic-team level, we replicated the strong additive effects of ability demonstrated previously in the literature (e.g., Tziner & Eden, 1985). Uniformly high-ability teams outperformed mixed-ability teams, who in turn outperformed uniformly low-ability teams. Although the performance effects were in the expected direction, we obtained mixed findings regarding the potential nonadditive effects of uniformly high-ability teams. That is, the difference in performance between uniformly high-ability teams and mixed teams was greater than the difference in performance between mixed-ability teams and low-ability teams; however, the direct comparison of these differences did not reach statistical significance. Nevertheless, our results are consistent with the notion that uniformly high-ability teams can achieve performance levels beyond that expected by summing the abilities of individual team members. Given the lack of studies that have addressed nonadditive effects of ability with experimental designs, we believe that this study makes an important contribution to the literature on team performance.

This study also makes a unique contribution to the intelligence literature by demonstrating the simultaneous effects of intelligence at the interindividual and individual levels. Not only did we show how individual intelligence affects team performance in training, but we also showed how individual learning is affected by team performance during training and the intelligence of one's training partner. Our results indicate that individual skill acquisition is positively correlated with team performance during training and that the intelligence of a training partner can influence a trainee's acquisition of a complex skill, depending on the intelligence of the trainee. Specifically, the performance of low-ability trainees was not much better when they trained with high-ability partners compared to training with other low-ability partners, but the performance of high-ability trainees was significantly higher when they trained with other high-ability partners compared to training with low-ability partners. In fact, in terms of binomial effect size displays (Rosenthal & Rubin, 1982), our findings indicate that training with a high-ability partner increases the probability of achieving success in training by 23% for high-ability trainees, but, for low-ability trainees, the chances for success only increase by 8%.

The team- and individual-level results are consistent with previous claims that positive nonadditive effects are most likely to occur when there are slight differences in ability between partners of relatively high ability (Gordon, 1997). Uniformly high-ability teams outperformed high-ability individuals more so than uniformly low-ability teams outperformed low-ability individuals. Mixed teams did not outperform the high-ability individuals from mixed teams, showing that team performance can be undermined by low-ability individuals or minimally that the contributions of low-ability members to mixed teams are superfluous to the contributions of high-ability members (Laughlin & Johnson, 1966). The unique contribution of the present study is that we show that the redundancy of low-ability partners to mixed-ability teams is manifested at the team-level and then carries over to the individual level by preventing high-ability partners from reaching their individual potential. This is particularly true from a ZPD perspective, such that high-ability individuals are not sufficiently challenged beyond their performance capacity in mixed-ability pairings (Hogan & Tudge, 1999).

Consistent with previous research (Fuchs et al., 1998), the difference in partner effects between high- and low-ability individuals may stem from the nature of the interactions that took place between partners during training. Our results showed that high-ability trainees who were paired with low-ability partners reported the lowest levels of cohesion. This finding is important because our results also showed that cohesion was positively correlated with individual performance, except for low-ability individuals who trained with low-ability partners. Furthermore, the positive correlation between individual performance and communication for low-ability trainees who trained with high-ability partners highlights the importance of effective communication between partners for low-ability trainees in heterogeneous training teams. That is, the extent to which low-ability trainees learn in mixed-ability training teams may be a function of the communication patterns that take place between trainees. However, this observed relationship was correlational in nature; thus, causal conclusions should be made with caution. For instance, early performance successes may have led to improved cohesion and communication rather than higher levels of cohesion and communication leading to performance improvements. Furthermore, a third variable could have accounted for this effect.

8.1. Implications

Given the extensive use of team-based training and instruction, the results of the present study have several practical implications. For instance, in educational and instructional settings where team-based projects and assignments are used (e.g., music and science classes in high school; MBA programs), the creation and composition of teams has implications, not only for the amount of learning that may be achieved by individual team members, but also the grades that they may earn. Specifically, our results suggest that the outcomes (i.e., grades and learning) attained by high-ability individuals may be more influenced by the ability level of their teammates than would be the case for low-ability individuals. Thus, it would seem that instructors need to be more sensitive to the composition of project teams especially when high-stakes outcomes are associated with said assignments.

Similar implications are also present in organizational contexts. For instance, if the goal of team-based training is for a select few—in terms of either team or individual performance—to reach exceptionally high levels of skilled performance, then high-ability individuals should be paired with other high-ability individuals. On the other hand, if the primary objective of training is to produce as many minimally satisfactory performing teams as possible, then it would be more effective to spread ability across teams by using mixed-ability teams. A third implication which is more legal and logistical in nature is germane in situations where performance in training and instruction is used as a criterion or predictor in future individual-level decisions. Specifically, the issue is one of making individual-level decisions based on performance outcomes that are partially influenced by factors (e.g., partner's ability) over which the individual has no control. Consequently, to resolve the confounds of training team assignment or partner's ability on a person's individual performance, personnel and education specialists may have to consider controlling for the influence of other teammates or partners' abilities when making decisions about job assignments or future training and instruction. Otherwise, using performance during training and instruction as a criterion or predictor under these circumstances may not be appropriate.

The above implications are derived from our finding that pairing low-ability individuals with high-ability individuals does not appear to facilitate individual skill acquisition for low-ability individuals when criterion performance involves a complex, difficult skill. Although one could conclude that such a finding shows that homogeneous pairing strategies do not adversely affect the learning of low-ability individuals, it offers little in the way of promoting higher forms of learning for low-ability individuals. Having noted this, it is also important to acknowledge that the structure of training in the present study was fairly low. With the exception of videotaped instructions and written manuals providing rules and strategies for performance, trainees received little guidance during practice. In their review of the literature on aptitude-treatment interactions, Snow and Lohman (1984) indicated that high-aptitude individuals benefit from learning programs low in structure, whereas low-aptitude individuals benefit from programs that are high in structure. In this regard, the unstructured nature of our training protocol may have been biased in favor of high-ability individuals. Based on the results of our interaction data, we suggest that structuring the interactions between training partners may enhance learning within mixed-ability training teams. Trainees could be taught how to effectively communicate and interact with each other to foster clear communication, positive exchange of ideas, regulation of learning and performance, and stimulation of novel insights. Partners could be assigned specific cognitive roles as opposed to cooperative roles to encourage high levels of interaction that challenge individual and interindividual thinking (Lumpe & Staver, 1995). Collaborative learners typically interact at basic levels unless they are taught specific skills that promote higher levels of discourse and elaboration of material (King, 1999). By teaching discourse skills and assigning cognitive roles to individuals, it may be possible to structure collaborative learning in a way that promotes higher forms of learning in low-ability individuals.

8.2. Limitations and future research

Certain methodological factors limit the generalizability of our findings and provide insight into future research needs. First, this was a laboratory investigation that utilized a sample of young adult males. Firmer conclusions regarding the generalizability of our results to a broader adult population require replications from field studies with older samples consisting of males and females (cf. Sanchez-Ku & Arthur, 2000). Second, we used a normative mean to create teams of different intelligence compositions that was based entirely on a college sample, and we restricted participation to only high- and low-ability individuals. As such, future research investigating the generalizability of our findings to noncollege samples, covering the whole range of ability compositions with larger sized teams, is warranted. Because our manipulation involved extreme differences, smaller effects could be observed with partners that have less disparity in intelligence.

Considerable evidence shows the intelligence–performance relationship is moderated by task factors at both the individual and team levels. For example, stronger correlations are found for more complex criteria (Gottfredson, 1997). Coupled with suggestions that the influence of various composition strategies may be moderated by task complexity (e.g., Fuchs et al., 1998), previous evidence regarding the moderating effect of task complexity indicates that conclusions regarding our results may be most appropriate for complex tasks involving interdependent components. The vast majority of previous studies on composition strategies have involved decision-making and reasoning tasks that did not have interdependent parts. For example, Laughlin and Johnson (1966) used an aptitude test consisting of synonym/antonym identification and analogies. From the ZPD literature, Tudge (1999) used a mathematical balance beam task that involved pictures of a beam on a fulcrum, with various weights positioned on the beam. For each picture, participants had to decide which direction the beam would tip or if the beam would be balanced. In other studies, participants learned facts and concepts in a given domain (e.g., Dossett & Hulvershorn, 1983). Although decision-making and reasoning are very important to most skills and disciplines, studies that use tasks that only rely on decision-making and reasoning do not fully capture the complexities found in many domains, especially considering the increased reliance on technology and human–machine systems found in education, military, and civilian work settings.

Furthermore, decision-making and reasoning tasks do not require or even foster the kind of collaboration and coordination needed to perform tasks that have interdependent components. This is problematic for studies of team-based and collaborative learning because it is assumed that partners in fact collaborate and coordinate when working. However, for decision-making and reasoning tasks, there is considerable variability in collaboration to the point that a single individual, likely the most competent member, could do all the work or individuals could divide items among themselves rather than working on each item jointly. Without constant monitoring for collaboration or structuring the task requirements such that coordination is required, it is difficult to draw inferences about pairing manipulations because collaboration and coordination will not be constant across conditions and could even be confounded with composition manipulations, with more collaboration found in homogeneous teams.

In military and civilian settings, work is increasingly becoming project-based, consisting of multiple parts that must be effectively coordinated for successful project completion. Projects are often complex, involving novel circumstances and time pressures. Consequently, projects are typically assigned to teams rather than individuals. In response to these work trends, collaborative team-based projects are increasingly used by educators to prepare students for future work demands (Johnson & Johnson, 2000; Michaelsen, Knight, & Fink, 2002). Educators frequently employ techniques (e.g., jigsaw; see Slavin, 1995) that require students to coordinate their individual efforts for both project completion and individual learning to be successful.

Therefore, to expand our understanding of how intelligence operates at an interindividual level and likewise form teams and collaborative learning groups, we recommend that researchers investigate the effects of task factors, like complexity and interdependence, in future experiments. For example, Saavedra, Earley, and Van Dyne (1993) showed that team performance was a function of a complex interaction between task, goal, and feedback interdependence, which was mediated by the degree of conflict within teams. In the present study, the nature of the task and the use of team-based rewards induced a high degree of interdependence between team members and consequently a high degree of collaboration and coordination. We believe that crossing manipulations of different interdependencies with composition strategies would better highlight the comparative effects of homogeneous versus heterogeneous compositions. In a similar vein, researchers should also examine the extent to which the effects of intelligence composition may be moderated by team processes by manipulating the nature of interaction patterns within teams. Because we examined the relationships between team interactions and individual performance using correlational data, causal conclusions should be made with caution. Future studies that explicitly manipulate the nature of team interactions as well as the intelligence composition of teams would provide more tenable causal conclusions regarding the relationships shared between the intelligence composition of teams, team processes during training, team effectiveness, and individual learning outcomes.

Another limitation of the present study is that our criteria only included assessments of performance during and at the end of a training program. Not only do we recommend that researchers expand outcome measures to tests of long-term retention and transfer to other tasks and contexts (Arthur, Day, Bennett, McNelly, & Jordan, 1997; Schmidt & Bjork, 1992), but we also believe future studies should examine the extent to which different pairing strategies used for a specific purpose (e.g., training) influence how well individuals are able to later work with new partners in different situations. For instance, high-ability individuals may benefit from training with high-ability partners in terms of immediate training performance, but how well can they adapt in future situations when they are paired with less capable partners? Although mixed-ability pairing strategies may not maximize training performance, mixed-ability strategies could help individuals learn to perform with partners of differing ability levels. Thus, we recommend that tests of transfer include ability-based assignments that differ from what individuals previously experienced.

8.3. Conclusion

Rather than focusing solely on individuals or teams and groups, we believe that examining how intelligence dually operates at individual and interindividual levels provides a more complete assessment of the impact of intelligence on learning and performance. Given the paucity of studies that have examined the effects associated with intelligence-based manipulations of teams and collaborative learning settings, the present study makes an important contribution to the intelligence literature by demonstrating the interplay of the effects of intelligence at individual and interindividual levels. In general, our results show a complex reciprocal relationship between the team- and individual-level effects of intelligence, with team effects having consequences for individuals depending on the intelligence of the individuals. Specifically, we found a strong additive influence of intelligence on team performance. Uniformly high-ability teams outperformed mixed-ability teams, who in turn outperformed uniformly low-ability teams. We also found modest nonadditive gains in performance for uniformly high-ability teams. At the individual level, better team performance was associated with higher levels of skill acquisition. In particular, the nonadditive gains of high-ability teams transferred to individual learning. High-ability trainees acquired significantly more skill when paired with other high-ability partners instead of low-ability partners; however, low-ability trainees benefited little from being paired with high-ability partners.

Acknowledgments

This research was sponsored under contract number F41624-95-C-5007 awarded to Winfred Arthur, Jr. from the U.S. Air Force Research Laboratory, Human Effectiveness Directorate, Warfighter Training Research Division, Mesa, AZ. The views expressed herein are those of the authors and do not necessarily reflect the official position or opinion of their respective organizations. Suzanne Bell is now at DePaul University. Bryan Edwards is now at Tulane University. Travis Tubré is now at the University of Wisconsin–River Falls.

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